ERDC/CERL TR-01-44

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Site Evaluation for Application of Fuel Cell Technology

Subase New London, Groton, CT

Michael J. Binder, Franklin H. Holcomb, and William R. Taylor

April 2001

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Construction Engineering Research Laboratory

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Foreword

In fiscal years 93 and 94, Congress provided funds for natural gas utilization equipment, part of which was specifically designated for procurement of natural gas fuel cells for power generation at military installations. The purchase, installation, and ongoing monitoring of 30 fuel cells provided by these appropriations has come to be known as the "DoD Fuel Cell Demonstration Program." Additional funding was provided by: the Office of the Deputy Under Secretary of Defense for Industrial Affairs & Installations, ODUSD (IA&I)/HE&E; the Strategic Environmental Research & Development Program (SERDP); the Assistant Chief of Staff for Installation Management (ACSIM); the U.S. Army Center for Public Works (CPW); the Naval Facilities Engineering Service Center (NFESC); and Headquarters (HQ), Air Force Civil Engineer Support Agency (AFCESA).

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Michael J. Binder. This report documents work done at Subase New London, Groton, CT. Special thanks is owed to the Subase New London points of contact (POCs), Steve Pucino and Herb Cummings, for providing investigators with access to needed information for this work. Part of this work was performed by Science Applications International Corp. (SAIC), under Contract DACA88-94-D-0020, task orders 0002, 0006, 0007, 0010, and 0012). The technical editor was William J. Wolfe, Information Technology Laboratory. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche, CEERD-CV-T. The Acting Director of CERL is William D. Goran.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Commander is COL James S. Weller.

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1 Introduction

Background

Fuel cells generate electricity through an electrochemical process that combines hydrogen and oxygen to generate direct current (DC) electricity. Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Air emissions from fuel cells are so low that several Air Quality Management Districts in the United States have exempted fuel cells from requiring operating permits. Today's natural gas-fueled fuel cell power plants operate at electrical conversion efficiencies of 40 to 50 percent; these efficiencies are predicted to climb to 50 to 60 percent in the near future. In fact, if the heat from the fuel cell process is used in a cogeneration system, efficiencies can exceed 85 percent. By comparison, current conventional coal-based technologies operate at efficiencies of 33 to 35 percent.

Phosphoric Acid Fuel Cells (PAFCs) are in the initial stages of commercialization. While PAFCs are not now economically competitive with other more conventional energy production technologies, current cost projections predict that PAFC systems will become economically competitive within the next few years as market demand increases.

Fuel cell technology has been found suitable for a growing number of applications. The National Aeronautics and Space Administration (NASA) has used fuel cells for many years as the primary power source for space missions and currently uses fuel cells in the Space Shuttle program. Private corporations have recently been working on various approaches for developing fuel cells for stationary applications in the utility, industrial, and commercial markets. Researchers at U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratories (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have successfully executed several research and demonstration work units with a total funding of approximately $55M.

As of November 1997, 30 commercially available fuel cell power plants and their thermal interfaces have been installed at DoD locations, CERL managed 29 of these installations. As a consequence, the Department of Defense (DoD) is the

owner of the largest fleet of fuel cells worldwide. CERL researchers have developed a methodology for selecting and evaluating application sites, have supervised the design and installation of fuel cells, and have actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers. This accumulated expertise and experience has enabled CERL to lead in the advancement of fuel cell technology through major efforts such as the DoD Fuel Cell Demonstration, the Climate Change Fuel Cell Program, research and development efforts aimed at fuel cell product improvement and cost reduction, and conferences and symposiums dedicated to the advancement of fuel cell technology and commercialization.

This report presents an overview of the information collected at Subase New London, Groton, CT along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report (see Table 1).

Objective

The objective of this work was to evaluate Subase New London as a potential location for a fuel cell application.

Approach

On 2 October 19964, Science Applications International Corporation (SAIC) visited the Naval Submarine Base New London (the Site) located in Groton, CT to investigate it as a potential location for a 200 kW phosphoric acid fuel cell. This report presents an overview of information collected at the Site along with a conceptual fuel cell installation layout and description of potential benefits. The Appendix to this report contains a copy of the site evaluation form filled out at the Site.

Table 1. Companion ERDC/CERL site evaluation reports.

Location	Report No.
Pine Bluff Arsenal, AR	TR 00-15
Naval Oceanographic Office, John C. Stennis Space Center, MS	TR 01-3
Fort Bliss, TX	TR 01-13
Fort Huachuca, AZ	TR 01-14
Naval Air Station Fallon, NV	TR 01-15
Construction Battalion Center (CBC), Port Hueneme, CA	TR 01-16
Fort Eustis, VA	TR 01-17
Watervliet Arsenal, Albany, NY	TR 01-18
911th Airlift Wing, Pittsburgh, PA	TR 01-19
Westover Air Reserve Base (ARB), MA	TR 01-20
Naval Education Training Center, Newport, RI	TR 01-21
U.S. Naval Academy, Annapolis, MD	TR 01-22
Davis-Monthan AFB, AZ	TR 01-23
Picatinny Arsenal, NJ	TR 01-24
U.S. Military Academy, West Point, NY	TR 01-28
Barksdale Air Force Base (AFB), LA	TR 01-29
Naval Hospital, Naval Air Station Jacksonville, FL	TR 01-30
Nellis AFB, NV	TR 01-31
Naval Hospital, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, CA	TR 01-32
National Defense Center for Environmental Excellence (NDCEE), Johnstown, PA	TR 01-33
934th Airlift Wing, Minneapolis, MN	TR 01-38
Laughlin AFB, TX	TR 01-41
Fort Richardson, AK	TR 01-42
Kirtland AFB, NM	TR 01-43
Subase New London, Groton, CT	TR 01-44
Edwards AFB, CA	TR 01-Draft
Little Rock AFB, AR	TR 01-Draft
Naval Hospital, Marine Corps Base Camp Pendleton, CA	TR 01-Draft
U.S. Army Soldier Systems Center, Natick, MA	TR 01-Draft

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

1 ft	=	0.305 m
1 mile	=	1.61 km
1 acre	=	0.405 ha
1 gal	=	3.78 L
°F	=	°C (X 1.8) + 32

2 Site Description

The Naval Submarine Base New London is located on the Atlantic seacoast approximately midway between the cities of Boston and New York. Situated on the east bank and approximately 6 miles from the estuary of the Thames River, the Naval Submarine Base lies within the two Connecticut Townships of Ledyard and Groton. The Base mission is to maintain and operate facilities to support training and experimental operations of the submarine force; to provide support to submarines, submarine rescue vehicles and assigned service and small craft; to provide support to other activities of the Navy and other governmental activities in the area; and to perform such other functions as may be directed by competent authority. The base has 7,900 military personnel and supports 5,600 military personnel afloat.

The ASHRAE design temperatures for the Site are about 50 and 90 °F. Extreme temperatures range from 100 °F to zero.

The Base energy plant, Bldg. 29, was investigated as a potential application for a 200 kW fuel cell. The energy plant has five boilers that produce steam for distribution throughout the Base all year round. The energy plant also houses one diesel generator and three steam turbine generators with a combined capacity of 15 MW. A 5 MW gas turbine generator is currently being installed.

Site Layout

Figure 1 shows the site layout for the energy plant. There is an open dirt area where the gas service is located on the east side of the building. The gas service adjacent to a room houses the electrical equipment for the new 5 MW gas turbine generator. The boiler feed water tank is on the opposite side of the building. The water treatment room in the southwest corner of the building produces deionized water, but the system is currently inoperable. The boilers are currently connected to a water softener system.

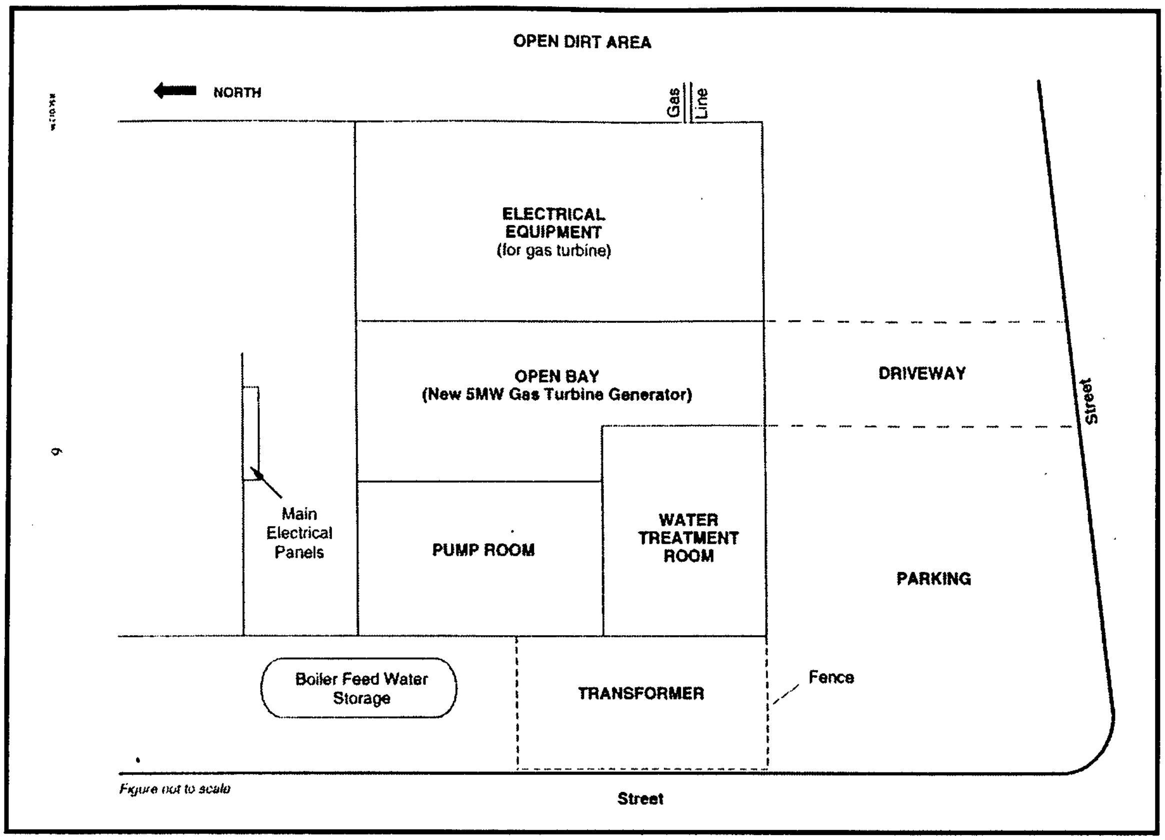

Figure 1. Naval Submarine Base energy plant site layout.

Electrical System

The energy plant uses 480V power fed through several transformers. The energy plant's main electrical panels are located just north of the open bay area. The electrical equipment for the new 5 MW gas turbine (east of open bay area) includes a 480/13,800V, 1,000 kVA transformer and a 480V electric panel.

Steam/Hot Water System

The energy plant produces 125 and 200 psi steam, which is sent throughout the Base. Each building has heat exchangers for generating hot water.

Space Heating System

Space heating is achieved through heat exchangers in individual buildings.

Space Cooling System

Cooling is not supplied by the central steam system except for two small (75 to 200 ton) absorption chillers located on Base.

Fuel Cell Location

The proposed location for the fuel cell is on the east side of the building (Figure 2). The dirt area adjacent to the gas service entrance is fairly flat and allows adequate space for the fuel cell. The fuel cell should run in the east-west direction as shown. The cooling module should run perpendicular to the fuel cell. Underground utilities and drain lines must be verified before final siting.

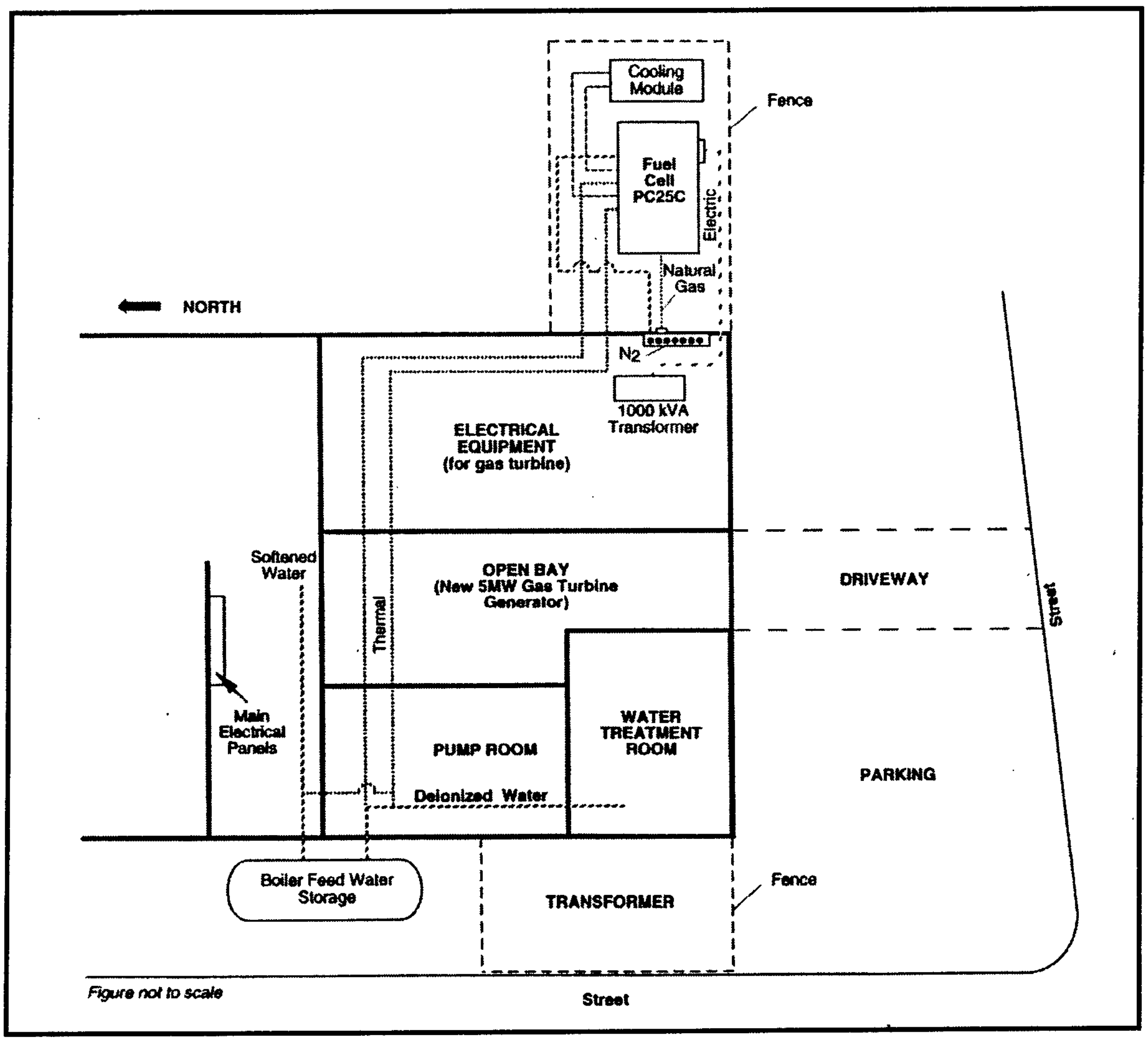

Figure 2. Fuel cell location and interfaces layout—energy plant.

The thermal piping run from the fuel cell to the boiler make-up line is about 200 ft in length. The fuel cell electrical output should be connected to the 480V side of the transformer in the new electrical equipment room (about 10 ft). The gas piping run is about 30 ft and the cooling module piping run is about 20 ft.

Fuel Cell Interfaces

The new electrical equipment installed with the 5 MW gas turbine generator includes a 480/13,800V, 1,000 kVA transformer. The grid connect output from the fuel cell should be connected to the 480 volt side of the transformer or to the 480V panel in the electric room. If the fuel cells 200 kW output is greater than the 480V load in the plant, the excess power will feed through the transformer into the Base grid. Base personnel should make sure that connecting the fuel cell at this point does not impact the warranty on the 5 MW gas turbine generator. The fuel cell will operate in the grid connect mode only, with no provisions for emergency back-up.

The fuel cell thermal output should be used to preheat the boiler make-up water. Under normal energy plant operation, deionized make-up water is fed to the boilers. However, this system is currently down for repair. When it will be put back into operation is not known. While the deionized water system is down, softened water from a separate system is used for boiler make-up. It is recommended that the fuel cell thermal be interfaced with both systems as (Figure 3). Stainless steel piping and fillings should be used to be compatible with the deionized water. Make-up water should be pulled from either the softened water line or the deionized water line heated in the fuel cell and returned to the boiler feed water storage tank. A 25 gpm pump should be used to control the flow through the fuel cell. This pump should operate whenever the fuel cell is operating.

The minimum make-up water requirement is about 15,000 lb/hr (30 gpm). The average make- up water temperature is about 550 °F. At the recommended 25 gpm flow through the fuel cell and at a temperature of 550 °F, the entire 700 kBtu/hr of thermal energy available from the fuel cell can be used. Since at the minimum make-up water flow, 100 percent of the fuel cell output can be used, no thermal storage is required. The fuel cell will heat 25 gpm of make-up water to 111 °F.

$$111\ °F = (700\ kBtu/hr)/((25\ gpm)(8.35\ lb/gal)(60\ min/hr)(0.001\ kBtu/hr - °F)) + 55\ °F$$

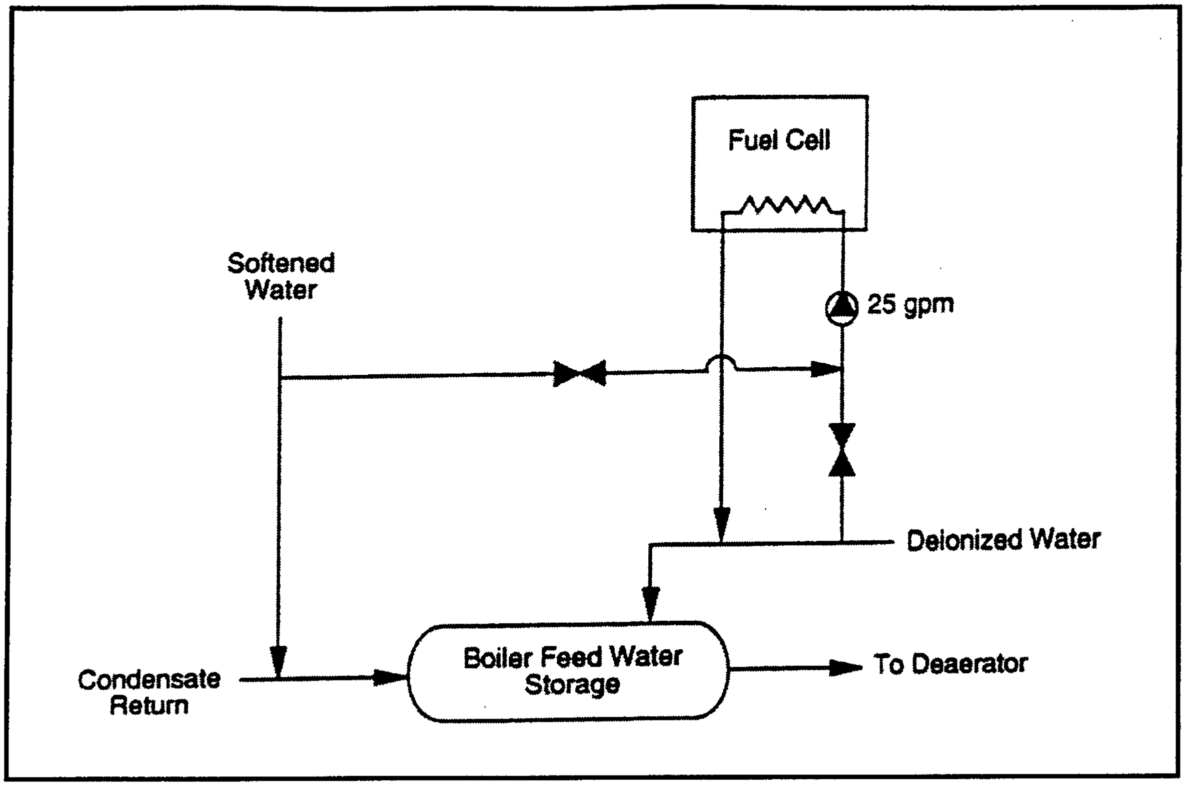

Figure 3. Fuel cell thermal interface—energy plant.

3 Economic Analysis

The Site is located in Groton Utilities' service territory. Table 2 lists electric bills obtained for September 1995 through August 1996. The average rate ranged from 5.84 cents/kWh in February to 6.26 cents/kWh in March. The average electric rate paid by the Site during this period was 6.06 cents/kWh. The site is billed under rate schedule LGS. The site is billed $27.50/kW for every kW of peak monthly demand. This "demand charge" includes 365 kWh per peak kW, which equates to an average of 7.53 cents/kWh. Additional kWh above 365 kWh/kW are charged at 4.23 cents/kWh. To be charged for kWh at this lower rate, the site load factor must be greater than 49 percent in a month:

(365 kWh / (1 kW * 24 hrs/day * 31 days/month)) 49 percent]

As listed in Table 2, the Site load factors ranged from 79 to 88 percent. Rate schedule LGS also has a demand ratchet of 90 percent of the greatest demand in the previous 11 months. The Site's actual peak demand was the indicated billed demand for all 12 months listed in Table 2 (in which no ratchet charge was invoked). There were actually 4 months where the ratchet should have been invoked, but the Site made special arrangements with Groton Utilities.

Table 2. Electricity consumption and costs for Naval Submarine Base New London

Date	Billing Days	Peak kW	Total kWh	Total Bill	S/kWh	Capacity Factor
Sep-95	32	19,620	12,960,000	$760,070	$0.0586	86%
Oct-95	29	19,512	11,664,000	$707,663	$0.0607	86%
Nov-95	32	19,620	12,672,000	$750,335	$0.0592	84%
Dec-95	29	21,528	12,576,000	$769,149	$0.0612	84%
Jan-96	31	22,176	13,704,000	$822,534	$0.0600	83%
Feb-96	32	19,764	13,368,000	$780,741	$0.0584	88%
Mar-96	28	22,932	12,528,000	$784,293	$0.0626	81%
Apr-96	30	21,852	12,648,000	$776,990	$0.0614	80%
May-96	29	19,584	10,800,000	$675,184	$0.0625	79%
Jun-96	32	21,420	13,176,000	$793,889	$0.0603	80%
Jul-96	30	19,368	10,944,000	$678,443	$0.0620	78%
Aug-96	33	19,692	13,104,000	$794,767	$0.0607	84%
Total/Avg	367	20,589	150,144,000	$9,094,057	$0.06057	83%

In months where the Site monthly demand falls below the 90 percent ratchet demand, no demand savings would be attributable to the fuel cell because the Site would be charged for kW above its actual peak demand. Although the ratchet did not take effect between September 1995 and August 1996, it has in the past and this additional cost could impact fuel cell economics. Attributing demand charge savings to the fuel cell becomes complicated when the 90 percent ratchet is invoked in any succeeding month after installation of the fuel cell. In circumstances where a new Site peak demand is established when the fuel cell is operating at 200 kW, the fuel cell could take credit for 9000 (180 kW) of the fuel cell demand savings because the new ratcheted demand level would be 200 kW lower than without the fuel cell installed.

The Site purchases natural gas from Yankee Gas Services Company under rate schedule 27 (firm gas). Table 3 presents natural gas consumption and costs for the period of September 1995 through August 1996. The gas commodity rate is \$0.2833/Ccf (about \$2.833/MBtu) for the 7 months of April through October and \$0.5255/Ccf (about \$5.255/MBtu) for the 5 months of November through March. The Site generally does not purchase natural gas during the 5 winter months of November through March. The Site purchases fuel oil at the equivalent of \$4.43/MBtu (\$0.62/gal at 140,000 Btu/gal). The Site must still pay a winter billing demand charge of \$1.25/Ccf based on a minimum demand of 500 Ccf/month (\$625/month in winter).

Table 3. Natural gas consumption and costs for Naval Submarine Base New London.

Date	Peak CCF	Total CCF	Total Bill	$/CCF
Sep-95	18,300	254,900	$87,616	$0.344
Oct95	—	—	$975	—
Nov-95	300	700	$2,363	$3.376
Dec-95	16,100	66,700	$60,695	$0.910
Jan-96	—	—	$975	—
Feb-96	—	—	$975	—
Mar-96	—	—	$975	—
Apr-96	35,500	759,400	$272,385	$0.359
May-96	20,100	474,200	$170,075	$0.359
Jun-96	27,000	431,000	$151,566	$0.352
Jul-96	19,300	435,300	$154,723	$0.355
Aug-96	24,700	609,500	$221553	$0.363
Total/Avg	20,163	3,031,700	$1,124,875	$0.371

The electric energy savings from the fuel cell was calculated based on 4.23 cents/kWh, since the site electric load factor is always greater than 49 percent. At a fuel cell capacity factor of 90 percent (1,576.800), this results in fuel cell energy savings of $66,698. Additionally, since the fuel cell can reduce the peak demand of the Site by 200 kW, a monthly credit of $5,500 is attainable ($27.50/kW 200 kW). If the fuel cell operates during the monthly peak demand period each month, then demand savings of $66,000 per year are possible. Total electricity energy savings from the fuel cell would be $132,698.

Table 4 lists the results for a number of fuel cell energy savings scenarios. The energy plant should utilize all the fuel cell thermal output. During times when the energy plant is shut down for repair, less than 100 percent thermal utilization would be achieved. Three thermal utilization scenarios were evaluated: 100, 90, and 75 percent. For electric demand reduction from the fuel cell, full demand savings, 50 percent demand savings and no demand savings scenarios were calculated. The results in Table 3 show net savings of $100,968 for the 100 percent thermal utilization and full demand savings scenario. If only 6 months' of fuel cell demand savings can be realized (fuel cell is down during peak demand period in 6 months), then net savings would be reduced by $33,000 (to $67,968).

This analysis is meant to give a general overview of the economics. For the first 3 to 5 years, ONSI will be responsible for the fuel cell maintenance. Maintenance costs are not reflected in this analysis, but could represent a significant impact on net energy savings. Since load profile data were not available, energy savings could vary depending on actual electrical and thermal utilization.

Table 4. Economic Savings of fuel cell design alternatives.

Case	ECF	TU	Displaced kWh	Displaced Gas (MBtu)	Electrical Savings	Thermal Savings	Nat. Gas Cost	Net Savings
A - Max. Thermal	90%	100%	1,576,800	7,357	$132,698	$25,738	$57,468	$100,968
A - 90% Thermal Utilization.	90%	90%	1,576,800	6,621	$132,698	$23,164	$57,468	$98,394
A - 75% Thermal Utilization	90%	75%	1,576,800	5,518	$132,698	$19,303	$57,468	$94,534
B - Max. Thermal	90%	100%	1,576,800	7,357	$99,698	$25,738	$57,468	$57,968
B - 90% Thermal Utilization.	90%	90%	1,576,800	6,621	$99,698	$23,164	$57,468	$65,394
B - 75% Thermal Utilization	90%	75%	1,576,800	5,518	$99,698	$19,303	$57,468	$61,534
C - Max. Thermal	90%	100%	1,576,800	7,357	$66,698	$25,738	$57,468	$35,968
C - 90% Thermal Utilization.	90%	90%	1,576,800	6,621	$66,698	$23,164	$57,468	$32,394
C - 75% Thermal Utilization	90%	75%	1,576,800	5,518	$66,698	$19,303	$57,468	$28,534

Assumptions:

Input Natural Gas Rate (Winter):	$5.26 /MBtu
Input Natural Gas Rate (Summer):	$2.83 /MBtu
Displaced Fuel Rate (Winter:):	$4.43 /MBtu ($0.63/gallon-oil)
Displaced Fuel Rate (Summer):	$2.83 /MBtu
Displaced Electricity Rate:	$0.0423
Fuel Cell Thermal Output:	700,000 Btu/hour
Fuel Cell Electrical Efficiency (HHV):	36%
Seasonal Boiler Efficiency:	75%

CASE A: full fuel cell demand savings

CASE B: 50% of full fuel cell demand savings

CASE C: zero fuel cell demand savings

ECF = Fuel cell electric capacity factor

TU = Thermal utilization

4 Conclusions and Recommendations

This study concludes that the energy plant building at Subase New London represents a good application for a 200 kW fuel cell at the Site. Thermal utilization should be nearly 100 percent. Electric savings could be as high as $132,698, depending on the actual demand savings for the Site as driven by the utility ratchet clause.

There is adequate space for the fuel cell in the area near the existing gas meter. The thermal interface is 200 ft away into the boiler feed water storage tank. Stainless steel piping and fittings will need to be used due to the deionized water. Both the gas line and electrical interfaces are relatively close (30 to 50 ft away). A security fence will be required.

Appendix: Fuel Cell Site Evaluation Form

Site Name: **Naval Submarine Base**
Location: **Groton, CT**

Contacts: **Steve Pucino**

1. Electric Utility: **Groton Utilities**
   Contact:
   Rate Schedule: **Large General Serv.**

2. Gas Utility: **Yankee Gas**
   Contact: **Ted Bates**
   Rate Schedule: **27**

3. Available Fuels: **Natural Gas/Fuel Oil**
   Capacity Rate:

4. Hours of Use and Percent Occupied:
   Hospital 28% occupied

Weekdays	5	Hrs.	24
Saturday	1	Hrs.	24
Sunday	1	Hrs.	24

5. Outdoor Temperature Range: **Teens - >100 °F**

6. Environmental Issues: **Fuel cell emissions expected to be lower than Connecticut standards**

7. Backup Power Need/Requirement:
   300 kW at Hospital
   1.5 MW at Energy Plant

8. Utility Interconnect/Power Quality Issues: **None**

9. On-site Personnel Capabilities: **Central plant personnel available on-site. Yankee gas will provide service**

10. Access for Fuel Cell Installation: **Proposed site is right next to road**

11. Daily Load Profile Availability: **None for hospital; minimum load for energy plant is 15,000 lbs/hr.**

12. Security: **Fence will be required**

Site Layout

Facility Type: **Central Energy Plant Age: >50 years**

Construction: **Steel/Concrete**

Square Feet: **About 50,000 sq ft**

See Figure 1

Electrical System

Service Rating: **13,800 volts service distribution on base, 480/277 and 120/208 volt service in building**

Electrically Sensitive Equipment: **Bailey Infi 90 DCS**

Largest Motors (hp, usage):

Grid Independent Operation?: **Hospital was interested in emergency load capability for chillers**

Steam/Hot Water System

Description: **4 X 76,000 lb/hr; 1 X 74,000 lb/hr boilers**

System Specifications:

Fuel Type: **Natural gas/oil**

Max Fuel Rate:

Storage Capacity/Type:

Interface Pipe Size/Description: **4-in. stainless steel to water treatment**

End Use Description/Profile:

Space Cooling System

Description: **2 absorption chillers supplied by steam system**

Air Conditioning Configuration:
Type:
Rating:
Make/Model:

Seasonality Profile: **No data available**

Space Heating System

Description: **Heat exchangers in buildings.**

Fuel:

Rating:

Water supply Temp:

Water Return Temp:

Make/Model:

Thermal Storage (space?):

Seasonality Profile: **None available**

Billing Data Summary

ELECTRICITY

	Period	kWh	kW	Cost
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10				
11.				
12.				

NATURAL GAS

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

OTHER

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

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8
4/01

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Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Researchers at the U.S. Army Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93). CERL has selected and evaluated application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to the manufacturer for commercially available fuel cell power plants installed at Department of Defense (DoD) locations.

This report presents an overview of the information collected at Subase New London, Groton, CT, along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report.

15. SUBJECT TERMS
energy conservation
fuel cells
fuel technology alternatives
Subase New London, Groton, CT

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					19b. TELEPHONE NUMBER (include area code) (217) 373-7214